WALKING DISTANCES TO BUS STOPS IN WASHINGTON, D. C. RESIDENTIAL AREAS

by Stephen G. Petersen

Introduction

WALKING DISTANCE must be a principal consideration in locating bus routes and stops to serve residential areas. Unless a bus line is located within what people consider a reasonable walking distance, the best equipment and schedules will not encourage their patronage.

Many efforts are underway by government and private agencies at all levels to encourage usage of buses and other mass transportation vehicles, particularly for work trips. However, investigations preliminary to undertaking the study covered in this article revealed little literature that has application to walking behavior as related to public transportation. A potential area for the extension of mass transportation is feeder-bus operation in conjunction with rail transit systems. The heart of this operation is the ability to extend service into areas where previous all-bus systems could not practically go and still haul passengers into downtown. Walking distance will have to be one factor in establishing these routes. (Other considerations are set forth in a procedure manual prepared by the National Committee on Urban Transportation.[1])

In fact, walking distance to and from bus stops can be a governing factor in determining the feasibility of serving typical single-family subdivision developments, with their large blocks and curvilinear street patterns. One example of where walking distance is being used as a criterion in designing a city is the new town of Columbia, Maryland. The overall plan for the community includes a mass transportation system so located that one-third of all the people in the community will be within 500 feet of the line, which will have stops at ¼-mile intervals.

Transit operators use, as a rule of thumb, a distance of one-fourth mile on each side of the line from which they can expect to draw riders. However, this is an oversimplification. Are people one-fourth mile away as likely to walk to the transit stop as those only 300 feet away? Probably not; but what does the curve of diminishing patronage look like? How is it affected by trip purpose? Car ownership? Economic status? These questions intrigued the author and they imply the objective of the work described here; namely, to determine how far people will walk from their home to a bus stop considering car ownership and socio-economic status.

Source Data

A 1966 survey of bus riders in the Washington, D.C. area was the basic source of data used in the author's study. In the survey, a total of almost 117,000 responses were received from riders on the routes of four bus companies serving Washington, D. C. Because the scope of the survey sample was too large for the author's study it was narrowed by imposing several limitations.

(1) The selection of data was limited to 50,000 coded cards of 85,000 returned by riders of the largest transit company (D.C. Transit).

(2) Since the greatest concentration of D.C. Transit patronage is within the District of Columbia, only responses from within D. C. were selected.

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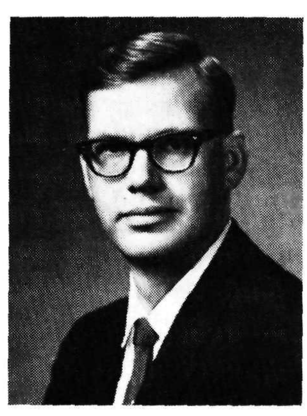
Mr. Petersen's Traffic Engineering **article is a condensation of the thesis which he prepared for the Catholic University of America in partial fulfillment of the requirements for his Master's degree.**



(3) Only selected bus routes sufficiently isolated from parallel routes serving the same destination (usually downtown) were scheduled so only one route was reasonably accessible to a person walking to the stop.

(4) Only walk trips to the bus stop were selected from the various modes of arrival provided on the questionnaire.

The original questionnaire completed by bus riders the day of the origin-destination survey (a part of the 1966 bus survey) was the source of data used in this study. A questionnaire survey card (Figure 1) was handed to each rider headed inbound to the CBD between 8:00 a.m. and 2:00 a.m. of the following day. A total of almost 190,000 survey cards were passed out to D.C. Transit riders. Another 51,000 cards were handed to riders on the three other bus lines. Of the 48 percent of the survey cards returned by riders, 59 percent were selected for coding and processing. Much of the data processing for the survey was related to determining origin-destination information, but several characteristics of the sample are pertinent for this study.

The sample selected for processing represented a total of about 249,700 trips over all routes of the four bus companies — excluding those with a school purpose, which were not surveyed. Of these, 196,000 (79 percent) stated "home" as the origin. The number of trips made from the home for various

TO BUS RIDERS: Please help to plan your future bus and subway systems by telling us ABOUT THE TRIP YOU ARE NOW TAKING. Drop completed card in box at door or hand to driver. If you don't have a pencil now, the card can be mailed free.

BUDGET BUREAU NO. 117-6601

1. I got on this bus at ________ (NEAREST STREET CORNER) (CITY OR COMMUNITY)
2. I have come from: ☐home ☐work ☐shopping ☐school ☐other
3. This place I have come from is at ________ (ADDRESS OR NEAREST CORNER) ________ (CITY OR COMMUNITY)
4. I am getting off this bus at ________ (NEAREST STREET CORNER) (CITY OR COMMUNITY)
5. I am now headed for: ☐home ☐work ☐shopping ☐school ☐other
6. This place I am headed for is at ________ (ADDRESS OR NEAREST CORNER) ________ (CITY OR COMMUNITY)

Nº 465003

PLEASE FILL OUT BOTH SIDES

UNITED STATES GOVERNMENT NATIONAL CAPITAL TRANSPORTATION AGENCY

PLEASE FILL OUT BOTH SIDES

7. How did you get to this bus: ☐Walked ☐Drove and Parked ☐Car Passenger ☐Bus ☐Train ☐Taxi or Other
8. How will you get from this bus to where you are headed: ☐Walk ☐Bus________ (Route Number of bus transferred to) ☐Car ☐Taxi or Other
9. Check the number of cars in your household: ☐None ☐1 Car ☐2 Cars ☐More than two

IF YOU TRANSFER ON THIS TRIP PLEASE DO NOT TAKE ANOTHER CARD

THANK YOU

UNITED STATES GOVERNMENT NATIONAL CAPITAL TRANSPORTATION AGENCY WASHINGTON, D.C. 20432

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20005

Fig. 1 — The bus rider origin-destination survey card.

purposes were:

Work	162,700	(83%)
Shopping	7,800	(4%)
Other	25,500	(13%)

The mode of travel from origin (not necessarily home) to the bus stop was also developed from the combined returns of all the bus companies. This analysis showed that 90 percent of all riders walked to the bus stop. The remainder arrived at the bus stop by automobile, except for a small number (½ percent) who came by other modes. These figures are for the entire area covered by bus service. Within the District of Columbia the percentage of those who walked to bus stops is even higher.

Selection of Study Sample

The first step toward selection of the study sample was to choose the bus routes which would be investigated. The criteria for selection were twofold:

- Routes covering all areas of the District of Columbia were desired thus to obtain a spread of socio-economic characteristics.
- The spread between routes was to be great enough, to the extent possible, so that a person *would be essentially limited to* one route serving a particular destination.

Based on these criteria, the responses from sixteen bus routes selected for coding in the 1966 bus survey were chosen for analysis, providing a sample of about 10,400 cards.

Sorting Operations

The questionnaires from the sixteen routes were handsorted to select the walk trips, which were then subdivided by purpose and by car ownership. The results demonstrated that only work trips by persons with either no car or one car had produced large enough samples with which to work. The original 10,400-card sample was then down to 4,085 cards. A comparison of the sample with the general characteristics cited previously revealed reasonable agreement.

Plotting Process

These 4,085 questionnaires, representing work trips by persons with a car ownership of zero or one, formed the basis for the last and most tedious step in processing the study sample. Walking distances are relatively small compared to any zoning system applied to the District of Columbia for any other purpose. Thus the only recourse was to plot each end of the *walk link and measure by hand the* length of the logical walk path.

The plotting process turned up

addditional questionnaires which had to be discarded for one or more of several reasons, the most common of which was links for walk trips not on the bus line being studied. Many of these could have been plotted for other bus routes, but it was decided to limit the plotting to the previously selected routes. Other reasons for discarding questionnaires were incomplete entries, illegible entries, nonsensical combinations resulting from omission of house numbers or cross streets. Consequently, the original sample of 4,085 questionnaires diminished to 2,448 plottable walk trips, ranging in length from a few feet to over a mile.

Walking Distance Distributions

The District of Columbia has a breadth of economic and social conditions. Some measure of these conditions was necessary to obtain valid consideration of walking distance distributions. Such a measure is found in the Socio-Economic Status (SES) index, one of three sets of indices derived from a study which developed a method for objectively classifying neighborhoods in the Washington Standard Metropolitan Statistical Area.[2] The other two were a Household Composition Index and an Age Status Index. These three indices can be combined to form a three-dimensional model of each census enumeration district in the District of Columbia, but the needs of this study were met by considering only the SES index. This index was divided into four levels (designated High, Medium, Medium-Low, and Low).

Once the four levels of the SES index were laid over the plotted walking distances, it was possible to read off the distances and record them in one of eight categories (four SES levels applied to two car ownership rates). A class interval of 200 feet was chosen and the eight distributions generated. A typical distribution is shown in Figure 2.

As a check on any bias in the selection of data from the source data, a comparison was made of the total number of observations in each SES class with the number

TABLE 1

Comparison of Sample Observations by SES Level With Percentage of Census Tracts at Each Level

SES Level	Number of Observations: No Car	One Car	Total	%	Census Tracts: Number	%
High	537	667	1204	49	38	32
Medium	255	178	433	18	30	25
Medium-Low	301	182	483	20	31	26
Low	229	99	328	13	21	17
Total	1322	1126	2448	100	120	100

TABLE 2

Summary of Statistical Values Developed for Eight Distributions and Formulas Used to Derive Them

Distribution Characteristics: SES	Car Ownership	N^a Sample Size	$\bar{x}^b$ Mean (feet)	s^c Standard Deviation	$s_{\bar{x}}^d$ Standard Error (feet)	$s_{\bar{x}}^2$
High	1	658	614	538	21.0	440
High	0	531	494	498	21.6	468
Medium	1	174	570	564	42.8	1830
Medium	0	252	596	500	31.5	992
Medium-Low	1	180	596	484	36.1	1302
Medium-Low	0	294	634	528	30.8	950
Low	1	91	700	542	57.9	3235
Low	0	223	727	542	36.3	1315

[a]The class interval was established at 200′ and the range from 0 to 2600′. Observations which exceeded 2600′ were excluded from these computations.

$$^{b}\bar{x} = \frac{\Sigma f_i x_i}{N} \quad \text{where } x_i = \text{midpoint of class interval}, \quad f_i = \text{number of observations for each class}$$

$$^{c}s = \frac{\Sigma f_i x_i^2 - \bar{x}\,\Sigma f_i x_i}{N}$$

$$^{d}s_{\bar{x}} = \frac{s}{\sqrt{N}}$$

of census tracts in that class in the District. The findings of this comparison (Table 1), show a bias in the data toward the highest SES class. One explanation for the bias

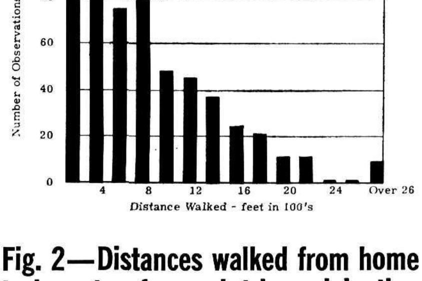

Fig. 2—Distances walked from home to bus stop for work trips originating in Washington, D. C.

is apparent when a map of the bus routes is overlaid with another showing SES levels. The bus routes are closest together in areas where the SES level is the lowest. Thus, because of the criteria established for selecting routes, fewer routes were eligible for investigation in the areas of lower SES levels; therefore, fewer observations were recorded in these areas.

Statistical Analysis

The standard expressions for determining the arithmetic mean and standard deviation were applied to each of the eight distributions. The results of these computations are shown in Table 2.

The mean walking distance ranges from a low of 494 feet to

a high of 727 feet and varies inversely with the SES level. Particularly noticeable in the step-wise progression is the increase in mean walking distance for non-car owners as the SES level decreases. In this instance, the sequence is 494, 596, 634 and 727 feet from highest to lowest SES level.

The mean walking distances for each distribution are interesting statistics, but the important question is whether the differences between each pair of distributions are real or result only from chance. To determine if the differences were significant, it was hypothesized that there was no difference between the means of each pair of distributions. A series of 28 computations for comparing each mean with every other mean were performed to test the hypothesis. The results of these computations (Table 3) bring the statistical analysis to a point where some results can be set forth.

TABLE 3

Matrix Showing Results of Tests for Significant Differences Between Means of Each of Eight Distributions

Distributions: SES	Car Ownership	High 0	Med 0	Med-Low 0	Low 0	High 1	Med 1	Med-Low 1	Low 1
High	0	-							
Med	0	0.01[a]							
Med-Low	0	0.01	No	-					
Low	0	0.01	0.01	0.05	-				
High	1	0.01	No	No	0.01	-			
Med	1	No	No	No	0.01	No	-		
Med-Low	1	0.05[b]	No	No	0.05	No	No	-	
Low	1	0.01	No	No	No	No	0.10[c]	No	-

[a]$z \geqq 2.58$ where z is the discrepancy between the observed difference in means and the hypothesized difference of 0 in the formula:

$$z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s^2_{\bar{x}_1} \quad s^2_{\bar{x}_2}}}$$

When the value of $z \geqq$ than 2.58 it indicates there is only a 1% probability that the difference between the means is due to chance as indicated by the entry 0.01.

[b]$z \geqq 1.96$ - 5% probability that difference in means is due to chance.

[c]$z \geqq 1.65$ - 10% probability that difference in means is due to chance.

Findings from Statistical Analysis

The distribution representing persons in the highest SES level without cars (shaded column of Table 3) is significantly different from six of the other seven distributions. At the 0.05 level or greater. The only difference not listed as significant at the 0.10 level actually was calculated to be 0.12. Thus, the hypothesis that there is no difference between the distribution representing persons at the highest economic level without cars and the other seven levels can be rejected. The first finding for work trips by bus is:

- People at the highest SES level who do not own cars have a significantly shorter mean walking distance to bus stops from a home origin than persons at lower SES levels and those who own cars regardless of level.

As depicted in Table 3, the distribution representing persons at the lowest economic level without cars (shaded row and column) is also significantly different from all other distributions at the 0.05 level with one exception. Again, because of the small size and large standard error for the distribution which was not significantly different, the hypothesis that there is no difference between this distribution and six of the other seven was rejected. The second finding about work trips by bus is:

- People at the lowest SES level who do not own cars have a significantly longer mean walking distance to bus stops from a home origin than persons in other classifications.

The fifteen remaining combinations of the possible 28 were found to be not significantly different except for one combination at the 0.10 level. This, therefore, left a large body of observations from six distributions between the two extremes that could be combined into one distribution containing 1,649 trips.

The values of the six combined distributions were then computed as:

Mean ($\bar{x}$)	610 feet
Standard deviation (s)	512
Standard error ($s_{\bar{x}}$)	12.6 feet
(Standard error)^2 ($s_{\bar{x}}$)^2	159

A test was also run to see if the omission of the high values up to 3,600 feet would change these values significantly. The test showed that these values could be omitted.

Using these values, this new distribution was compared with distributions at the extremes and was found to be significantly different from each at the 0.01 level. Thus, the third and fourth findings of this analysis of public transit work trips are:

- People at all SES levels who own one car have similar mean walking distances to bus stops from a home origin.
- People at Medium and Medium-Low SES levels who do not own a car have mean walking distances to bus stops from a home origin significantly different from, and about midway between, those at higher and lower SES levels and about equal to those who own one car.

The three distributions derived

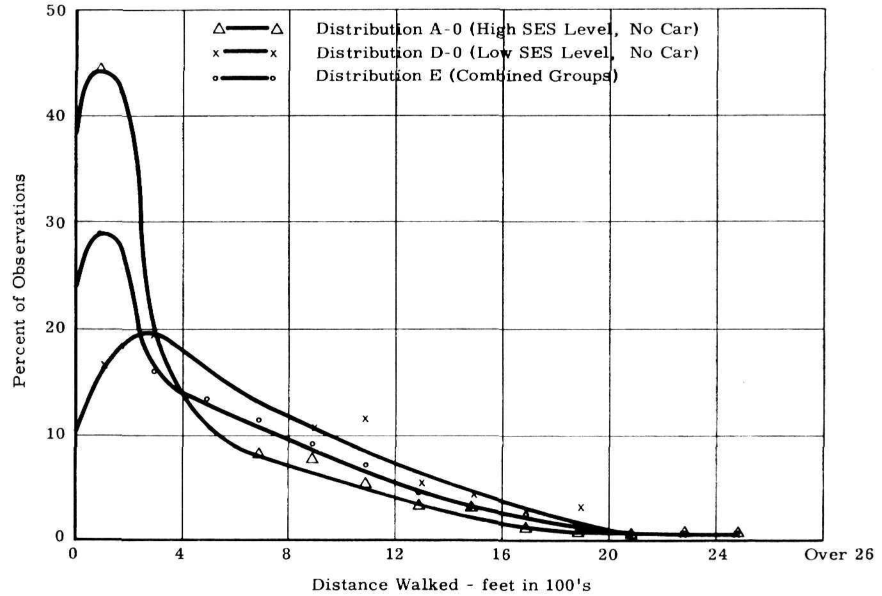

Fig. 3 — Percentage of people walking various distances to bus stop in residential areas of Washington, D. C. for three significantly different distributions.

from the analysis are shown in Figure 3 as hand fitted curves. The ordinate is in terms of percentage of observations which eliminates the differences due to sample size and which graphically demonstrates the increasing peakedness of the distributions as the SES level increases.

Conclusions

The statistical analysis demonstrated conclusively that persons at different socio-economic levels who do not own cars have distinctly different walking patterns for work trips. People at the highest levels walk significantly shorter distances than people at the lowest levels. On the other hand, ownership of an automobile seems to have a leveling influence, which is reflected in a narrower range of walking distances between people at the highest and lowest socio-economic levels. Persons from auto-owning households at all levels accept walking distances midway between the extremes found for persons from non-auto owning households.

In an effort to present the findings in a more definitive form, Figure 4 was developed showing accumulations of the data in Figure 3. Rather than develop it by starting with the shortest distance (as is the usual procedure), the accumulation was developed by starting with the longest distance. This procedure provides a more quickly assessable view of the impact of increased walking distance on the percentage of riders that may be expected to walk a certain distance. For example, assume that the development around a bus stop is of uniform density. Then at a distance of one-fourth mile the potential ridership has decreased to twenty percent of the persons living within that distance in an area with a low SES level, but is down to ten percent in an area with a high SES level. At 600 feet, the mean walking distance for the combined distribution, ridership is down to 37 percent in a high SES level area but still holding at 58 percent in an area of low socio-economic status.

The median walking distance can also be determined from Figure 4. For each of the distributions, the approximate median walking distance is:

High SES Level, No Car 400 ft.
Combined Distribution 560 ft.
Low SES Level, No Car 710 ft.

For purposes of comparison, a distribution for downtown Washington obtained from another study is also shown in Figure 4. Potential ridership drops much more quickly than at the residential end of the trip due largely, in all probability, to the closer spacing of bus lines and the greater opportunity for transfers (particularly if they are free, as in Washington).

It is appropriate at this point to review the questions asked at the beginning of this report. Taking each in turn, the findings just described show that potential ridership from persons with a work purpose decreases rapidly as distance from a bus line increases. The curves shown in Figure 4 can be used to measure this decrease.

Car ownership and socio-economic level have a distinct impact at the extremes of the economic scale, but the curve represented by two-thirds of the trips studied (combined distributions) provides a useful index of diminishing patronage as distance from a bus line increases.

Although over 2,400 trips were extracted from the 1966 bus rider origin and destination survey, not enough observations were available to deal with any purpose other than work trips. Thus, the question of the effect of purpose on walking distance cannot be answered by this study.

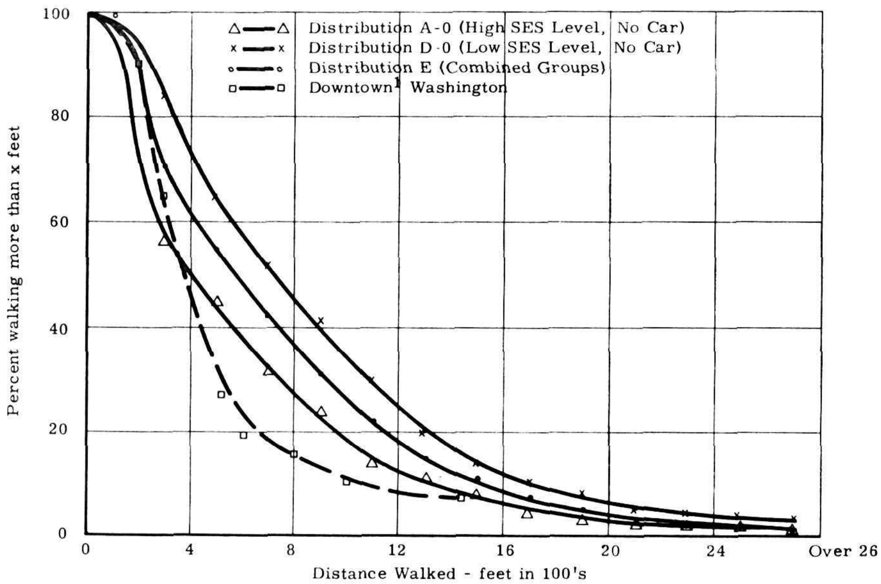

Fig. 4 — Percentage of people walking more than various distances to bus stops in residential areas of Washington, D. C. for three significantly different distributions compared to a downtown distribution.

[1]Source: Alan M. Voorhees and Associates, **Feasibility of Transit Service for Columbia** (Washington: By the author, 1964), Fig. II.

As one ponders the variables which can affect walking distance, it becomes apparent that this study has only scratched the surface of a broad area of investigation. For example, neither age nor sex of the riders was asked in the survey, nor was there a question as to the availability of the one or more automobiles owned by the household. These questions lead into a whole new area of whether or not the trip was by choice or would have been made by car if it were available.

If resources had permitted, it might have been interesting to explore ridership along particular routes or sections of routes for such factors as frequency of service and type of housing. For example, along Connecticut Avenue the non-car-owning households may be concentrated in apartments which front on the Avenue and thus may have biased the walking distance for high SES level people who do not own cars. Or, in the case of frequency of service, people might be more influenced to ride public transit if headways are short, thus reducing waiting time and requiring less planning to be at the pick up point at a specific time.

If the complaints which a transit operator receives can be used as a guide, there are a multitude of other factors which influence the individual's choice to ride transit. Some of these include such specifics as the steepness of a hill leading to the bus stop, the presence or absence of sidewalks and street lighting, the location of the downtown destination relative to the transit line serving the rider's neighborhood (the question of transfers), the cost of parking downtown, and the personal well-being of the rider.

The counterbalance of all these factors is the financial structure within which the transit operator must work. If all his needs must come from the fare box, he may not be able to provide all the specialized services that would be attractive to riders. Furthermore, physical factors external to the vehicle are usually the responsibility of public agencies which have other priorities to consider.

In conclusion, the author's study found some significant differences in walking distances at the extremes of the socio-economic scale and has defined a decay curve for the reduction in patronage as distance from the stop increases. These items of information should be useful in the layout of new transit routes for feeder-bus operations or in newly developed areas and for guiding the design of new towns which incorporate transit. However, they are only guides and the other factors mentioned above must be recognized as having an, as yet undefined, influence on the answer to the question "Should I take the bus?"

Recommendations

Additional work of a similar nature should be undertaken in other cities. With the ever increasing need to relieve peak traffic flows to the central areas of our major cities, all possible inducements for increasing transit must be explored. The phenomenon of acceptable walking distances seems at this point to be an orphan of more sophisticated technology.

Some facets recommended for further consideration include:

- Walking patterns in areas of single family residential development as contrasted to areas which have predominantly multi-family housing, as was the case along the routes selected for this study.

- The effect of closer spacing of bus routes, particularly in areas at the extremes of the socio-economic scale, with special recognition of the economic impact this may have on the operator.

- Methodology which will provide walking distances without the tedium (and expense) of plotting and measuring each individual observation.

- More data as to the effect of car ownership on public transit usage and walking distances, expecially for cases where there may be a choice between car and transit.

- Further exploration into the information which is included in the responses from the 1966 bus survey to develop additional insights into the characteristics of bus riders in the Washington Metropolitan Area.

- Adaption of the study method developed for the 1966 bus survey for use in other cities to provide similar comparative information with a smaller expenditure of resources, but at the same time attempting to gather details on age, sex, transit service and physical factors which may affect the choice between car and transit.

Acknowledgments

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COVER: Wilshire Boulevard in Los Angeles. The effects of applying paint channelization to this arterial are analyzed in a report beginning p. 22.
(Photo courtesy Los Angeles Dept. of Traffic)

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